Structure and changes of broad-leaved-conifer-Korean pine mixed forest in Northeast China[1]

Dai Limin (代力民) Liu Qijing(刘琪景) Zhang Yiping(章依平)
Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110015, P. R. China

Dong Shijie (董士杰)
Natural Protection Bureau of Changbai Mountain, Erdaobaihe, 133613, Jilin Province, P. R. China

Abstract The structure and species composition as well as their changes in a climax forest, dominated by *Pinus koraiensis-Tilia amurensis* and *Fraxinus koraiensis*, were observed with an interval of 10 years. The number of tree species was 16 in 1981, which was kept unchanged. Density was increased from 510 to 535 stems/hm^2, and basal area from 35.19 to 38.17 m^2/hm^2. Average stand DBH remained nearly unchanged. The total mortality of the stand was very low, 0.61% per year. *Fraxinus* and *Pinus* were declining in population size, the highest mortality rate for the former, and the largest death number for the latter. *Tilia* showed a rapid increasing of 14.9%, and the density of saplings (DBH 3-8 cm) was 71 stems/hm^2, led the top among canopy-layer species. *Acer mono*, similar to *Tilia*, showed a type of continuous regeneration which was represented by the reverse J-shape of DBH distribution and compensation ability to mortality. Sub-canopy species such as *Acer pseudo-sieboldianum*, *Maackia amurensis* etc. presented a stable status by self-maintenance. Based on the fact of the decreasing of dominant populations, it is predicted that the composition of the community was changing gradually, the rising of broad-leaved components versus the declining of coniferous species.

Key words: Species composition, Growth, Mortality, Recruitment

Introduction

The broadleaved-conifer mixed forest is widely distributed in northeast China. Many studies have been made on the structure and composition (Wang *et al.* 1980, Huang *et al*, 1993) as well as the succession (Miles *et al* 1983), but detailed information on the dynamics based on permanent plots is sparse, and the description on individual forest types is insufficient. This paper is intended as an investigation of the stand structure and its changes with time, based on the accurate data observed on a permanent plot.

Study area and methods

The study plot (128°07'E, 42°27'N) was located in the north slope of Changbai Mountain, northeast China, which was set in 1981 by the Changbai Mountain Research Station of Forest Ecosystem, Chinese Academy of Sciences. The plot was located at elevation 740 m as (Fig.1), and the size was 100m×100m. DBH>8.0 cm was recorded and labeled. Crown map was drawn. The second investigation was carried out in 1991 and 1992, without drawing the crown map, but DBH4-8 cm was added to the data set. Growth rate was represented by the ratio of actual increment of individuals marked in 1981 and survived in 1991,

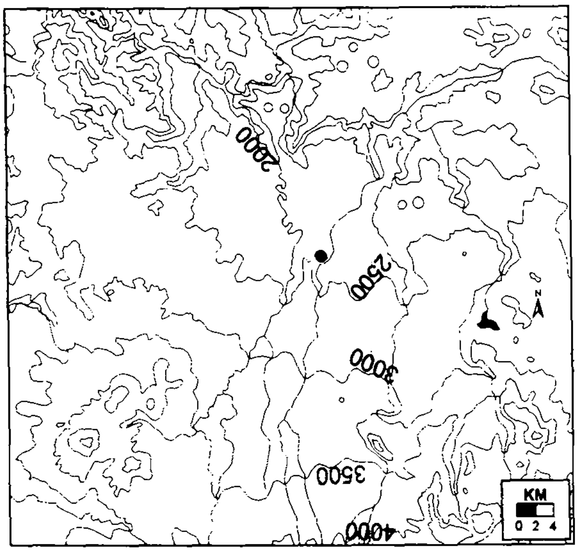

Fig.1. Topography of the study area
Note that contour line is denoted by ft(1 ft=0.3048m).

versus the size in 1981. Recruitment rate was expressed by the relative number of newly entered trees to the original density. Shrub layer was investigated by randomly sam-

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pling 150 individuals for determining the composition, and herb layer was recorded with density, height and coverage with 6 quadrats of 1m×1m.

Forest type was named by the sequence of the sum of relative density and relative basal area of tree species with relative basal area larger than 10%. Nomenclature followed An Enumeration of the Plants of Changbai Mountain, edited by Changbai Mountain Research Station of Forest Ecosystem, Academia Sinica, 1982. Plants that could not be identified to species level, e.g. no flowers, were assigned as morpho-species.

Results

Species composition and its changes

Community type of the study plot was *Pinus koraiensis*-*Tilia amurensis*-*Fraxinus mandshurica* forest. Sixteen tree species were identified in the plot. The dominant height of canopy layer was about 26 m, occupied by *Pinus*, and *Fraxinus*. Subcanopy layer, consisted of *Acer triflorum*, *A. pseudo-sieboldianum*, *Maackia amurensis etc.* with the height of 5-15 m, was lower in both density and basal area. Table 1 shows the composition and its change in a 10-year interval. Species richness was kept unchanged, but *Populus* that had only one individual in 1981 was replaced by a stem of *Juglans*. Species diversity showed a slight increasing. Species rank by relative basal area had no significant change. Subcanopy species showed more rapid in recruitment, because of the short life span, e.g. *Acer pseudo-sieboldianum* and *A. triflorum* and *Maackia amurensis* represented higher rates of ingrowth

Table 1. Tree species composition and changes in a 10-year period.

Species	DBH_1 /cm	DBH_2 /cm	RN_1	RN_2	RBA_1	RBA_2
Fraxinus mandshurica	48.8	47.9	0.0980	0.0916	0.2920	0.2681
Pinus koraiensis	25.3	28.4	0.2882	0.2542	0.2431	0.2581
Tilia amurensis	29.5	28.4	0.1745	0.1907	0.2151	0.2258
Acer mono	19.3	20.0	0.1706	0.1664	0.0848	0.0859
Quercus mongolica	42.4	44.9	0.0333	0.0318	0.0751	0.0775
Ulmus japonica	27.5	25.8	0.0431	0.0411	0.0558	0.0420
Acer pseudo-sieboldianum	11.4	12.0	0.0588	0.0710	0.0096	0.0125
Acer triflorum	12.7	13.5	0.0431	0.0467	0.0083	0.0098
Maackia amurensis	10.7	11.3	0.0412	0.0467	0.0056	0.0069
Phellodendron amurense	20.0	19.5	0.0078	0.0093	0.0039	0.0045
Acer tegmentosum	9.4	10.7	0.0275	0.0318	0.0028	0.0041
Tilia mandshurica	16.7	20.2	0.0039	0.0037	0.0013	0.0018
Acer mandshuricum	18.5	19.7	0.0039	0.0037	0.0016	0.0017
Betula platyphylla	14.1	12.1	0.0020	0.0037	0.0004	0.0006
Syringa amurensis	8.8	9.0	0.0020	0.0056	0.0002	0.0005
Juglans mandshurica	--	8.2	--	0.0019	--	0.0001
Populus davidiana	15.0	--	0.0020	--	0.0005	--
Total or average	25.2	25.4	1.0000	1.0000	1.0000	1.0000
Shannon's H' (nat)			2.0920	2.1532	1.7773	1.7938
Simpson's D			0.1631	0.1503	0.2068	0.2050.2

Note: RN and RBA represent relative number and relative basal area, respectively. Numbers 1 and 2 attached to the items represent the surveys in 1981 and 1991, respectively

Shrub layer consisted of 17 species, dominated by *Philadelphus schrenkii*, *Corylus mandshurica* and *Deutzia amurensis*(Table 2). Some large-size shrubs had lower density but higher coverage, such as *Acer barbinerve*, *Syringa amurensis*, *Acanthopanax senticosus*, *Acer tegmentosum*, and so on. Herb layer, with average height of 30 cm, contained 37 species, and it was dominated by *Meehania urticifolia*, *Carex pilosa* and *Brachybotris paridformis* (Table3). *Aegopodium alpestre*, *Thalictrum aquilegifolium* and *Anemone amurensis* were high in density but low in coverage. *Athyrium brevifrons*, *Paris verticillata*, *Adonis amurensis* and *Sanicula rubriflora* were common.

Table 2. Species composition of Shrub layer by relative density (N%)*. Based on 10 quadrats of 4m×4m

Species	%	Species	%
Philadelphus schrenkii	27.8	*Acanthopanax senticosus*	1.6
Corylus mandshurica	24.5	*Acer tegmentosum*	1.6
Deutzia amurensis	19.6	*Viburnum sargentii*	1.2
Acer barbinerve	5.7	*Euonymus pauciflorus*	0.8
Syringa amurensis	4.1	*Actinidia kolomicta*	0.8
Rosa acicularis	2.9	*Lonicera maximowiczii*	0.8
Lonicera chrysantha	2.0	*Euonymus alata*	0.4
Ribes mandshuricum	2.0	*Schisandra chinensis*	0.4
Viburnum brejaeticum	2.0	Total	100

*Number of species 17; total individuals 245; Shannon's index(nat) 2.07

Table 3. Composition of herb layer*

Species	IV %	Species	IV%
Meehania urticifolia	16.8	*Veratrum oxysepalum*	1.7
Carex pilosa	11.5	*Jeffersonia dubia*	1.5
Brachybotris paridiformis	9.0	*Sanicula rubriflora*	1.5
Cardamine leucantha	6.6	*Athyrium* sp	1.5
Aegopodium alpestre	5.9	*Filipendula palmata*	1.4
Thalictrum aquilegifolium	4.2	*Phryma letostachya*	1.3
Maianthemum bifolium	3.4	*Euphorbia lucorum*	1.1
Cacalia sp.	3.0	*Arisaema amurense*	1.0
Convallaria keiskei	2.6	*Enemion raddeanum*	0.9
Athyrium sp2	2.6	*Saussurea* sp2.	0.9
Aruncus sylvester	2.6	*Adenophora remotiflora*	0.8
Athyrium brevifrons	2.4	*Dioscorea nipponica*	0.7
Carex sp5	2.4	*Circaea quadrisulcata*	0.6
Paris verticillata	2.1	*Viola acuminata*	0.6
Lamium album	2.0	*Galium mandshuricum*	0.5
Carex sp4	1.9	*Impatiens noli-tangere*	0.5
Adonis amurensis	1.8		
Anemone amurensis	1.7	Total	100

Note: IV is importance value (%) represents dominance (relative projection volume + relative density + relative frequency)/3.
*Elevation is 740 m;, Number of species 32, Average cover 70%, and Dominant height is 30 cm

Size distribution of trees

The tree layer can be divided into at least two sub-layers. The high canopy-layer (>20 m) consisted of *Pinus, Fraxinus, Quercus, Tilia, Acer mono etc.* while thelow canopy-layer (5-20 m) contained *Acer pseudo-sieboldianum, Maackia amurensis, Acer triflorum* etc. DBH corresponded well with the vertical structure, the larger the higher. DBH distribution of the whole plot presented a typical reverse J-shape, with the larger number in lower DBH classes, and declined toward the larger classes (Fig 2). The size distribution was significantly different among species, i.e. the smaller classes were dominated by *Tilia* and *Acer mono*, in the high canopy-layer, and *A. pseudo-sieboldianum, A. triflorum* and *Naackia* in the subcanopy layer. All these species showed a property of good self-maintenance. Contrary to this, *Pinus* and *Fraxinus* displayed a normal mode that frequency was rising from the lower DBH limit, and having the highest value of 26 stems/.hm^2 at its intermediate class, and then dropping gradually toward the higher limit of DBH range. This may

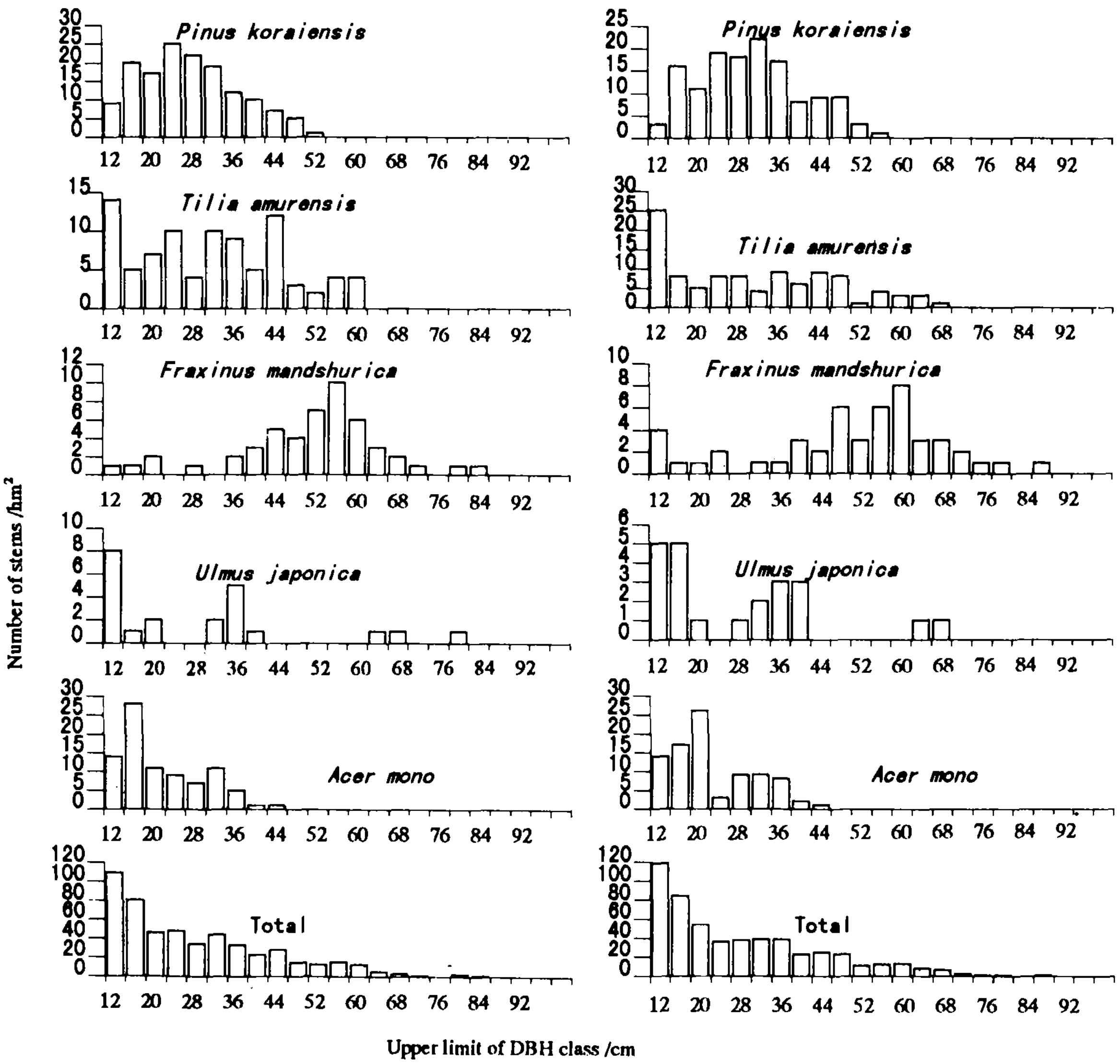

Fig.2. Size distribution of a broadleaved-conifer mixed forest in Changbai Mountain (Left for 1981, and right for 1991)

announce the establishment and development process, that the population had thrived by canopy releasing, and was currently oppressed. Some other high tree species, like *Ulmus* and *Quercus*, had wide DBH ranges but uneven frequencies. DBH distribution reveals the regeneration patterns, continuous and discontinuous, as indicated by Bongers *et al.* (1988) and Saxena *et al* (1984). *Acer mono, Tilia amurensis* corresponded with the former category, while *Pinus, Fraxinus* and *Quercus* comported with the latter.

Growth rate

The growth rates of density and basal area were 4.9% and 8.5%, respectively, but average DBH remained the same. The growth of standing trees which were recorded in 1981 and survived in 1991 is given in Fig.3. The increment was ranged from nearly 0 to the maximum of 10.2 cm . Most of the stems had increment less than 8 cm. Radius increment did not show significant correlation with DBH class, similar to the results reported by Primack *et al.* (1985). This variability was probably caused by the differentiation of vertical distribution among individuals, those standing in high layer with less suppression are considered having higher growth rate while those in crowding areas may decrease in growth rate because of the interfering by the neighboring individuals (Peterson *et al.* 1995). The maximum relative growth of each class, however, presented a typical reverse J-shape, fast at the young stage, with the value of 52%, and decreasing rapidly toward the larger individuals, and touched bottom finally (Fig 3).

Mortality and recruitment

Table 4 shows the mortality and recruitment patterns of each species. A total of 31 stems/hm^2 (basal area 22.74 m^2/hm^2) were dead, and the mortality rate was 6.1% by density, and 6.5% by basal area. Regarding with the death rate among high canopy-layer species, *Pinus* was the highest (2.2%) by density, while *Fraxinus* had the highest death rate by basal area. *Tilia* performed a relatively higher recruitment speed, and the population was increasing. Newly recruited young tree were mainly *Tilia* and some subcanopy species like *Acer pseudo-sieboldianum*. This pattern of density changes indicated that the dominant species, especially the high-canopy species, were in the condition of declining. The DBH distribution showed a similar form with that of the standing tree, the lower DBH class presented a higher frequency of mortality (Fig.4), implying the effects of canopy oppression on the individuals with lower height, but the inner-class mortality among larger ones was considerably high.

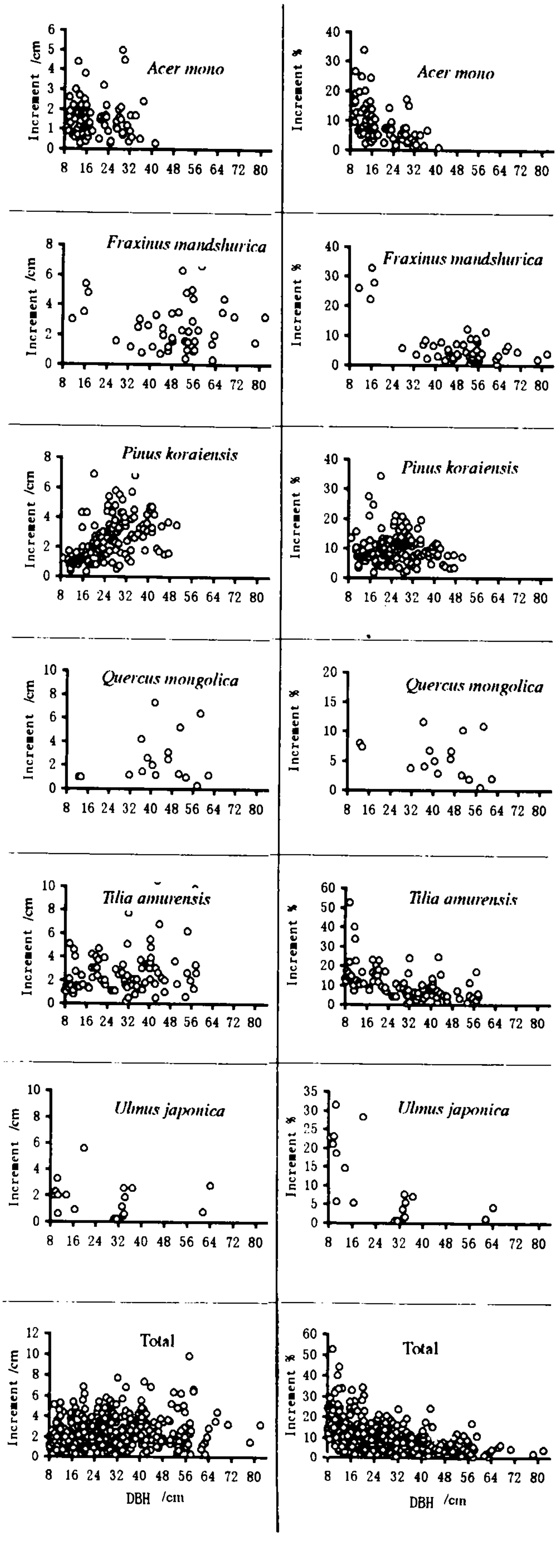

Fig. 3 DBH growth of the trees survived in 1991.

Table 4. Mortality and recruitment of the study plot..

Species	INGR	RINGR	ND	BAD	DBHD	RND	RBAD	RATEN	RATEBA
Fraxinus mandshurica	4	0.080	5	9639	49.1	0.010	0.027	0.100	0.094
Pinus koraiensis			11	3255	18.1	0.022	0.009	0.075	0.038
Tilia amurensis	17	0.191	4	2726	29.0	0.008	0.008	0.045	0.036
Acer mono	5	0.057	3	1302	22.4	0.006	0.004	0.034	0.044
Quercus mongolica	---	---	---	---	---	---	---	---	---
Ulmus japonica	2	0.091	2	5124	45.7	0.004	0.015	0.091	0.261
Acer pseudo-sirboldianum	11	0.367	3	253	10.2	0.006	0.001	0.100	0.075
Acer triflorum	4	0.182	1	189	15.5	0.002	0.001	0.045	0.065
Maackia amurensis	5	0.238	1	79	10.0	0.002	+	0.048	0.040
Phellodendron amurense	1	0.250	---	---	---	---	---	---	---
Acer tegmentosum	3	0.214	---	---	---	---	---	--	---
Tilia mandshurica	---	---	---	---	---	---	---	---	---
Acer mandshuricum	---	---	---	---	---	---	---	---	---
Betula platyphytla	1	1.000	---	---	---	---	---	---	---
Syringa amurensis	2	2.000	---	---	---	---	---	---	---
Juglans mandshurica	1	---	---	---	---	---	---	---	---
Populus davidiana	---	---	1	177	15 .0	0.002	0.001	1.000	1.000
Total or average	56	0.110	31	22744	25.5	0.061	0.065	0.061	0.065

Note: INGR and RINGR represent recruited number and relative recruitment, respectively; ND: dead stem-number per hm^2; BAD: dead basal area (cm^2/hm^2); DBHD: average DBH(cm) of dead individuals; RND: mortality rate of the whole plot by density; RBAD: mortality rate to the total number on stems on the piot by basal area; RATEN: species mortality rate by density; RATENBA: species mortality rate by basal area

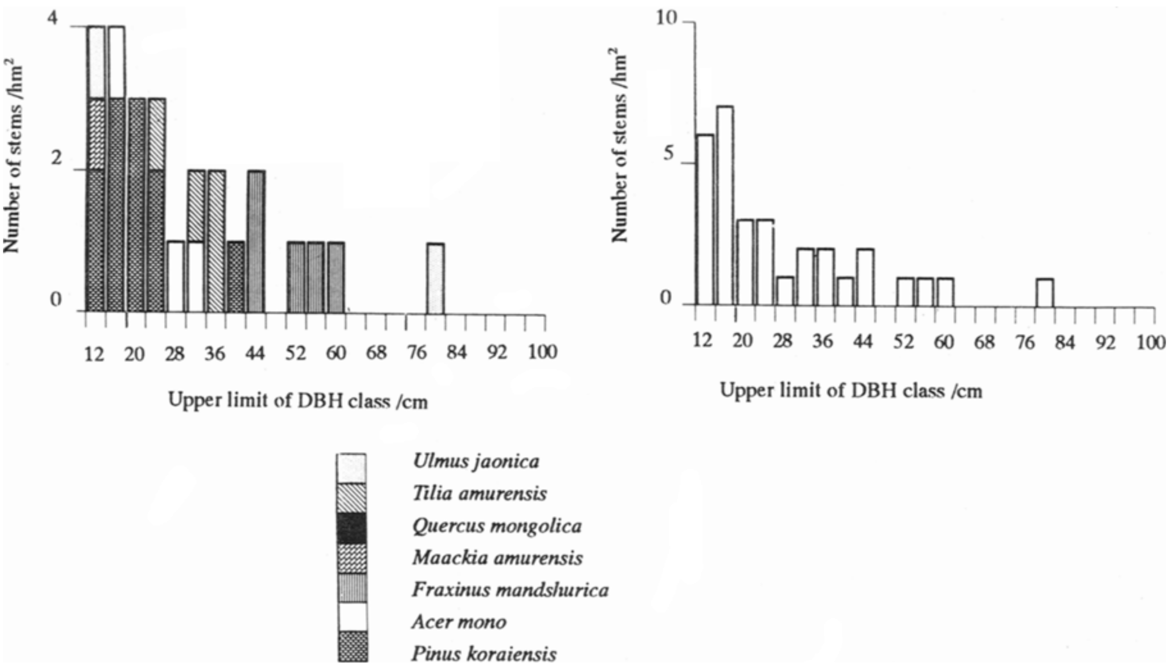

Fig.4. Size distribution of tree dead in the 10-year period
Left for total stand and right for main species.

Discussion

It is agreeable that the coniferous species, *Pinus*, tended to decreasing and deciduous components rising. Most of the species standing at high canopy-layer showed poor regeneration. Therefore, it has been concluded, by modeling the population dynamics, that deciduous species will become overwhelmingly dominant during succession (Miles et al. 1983). However, it can not answer the question that how the forest has been kept in the area. Species alternation is the result of competition for surviving as well as the consequence of environmental changes. The constitution may change dramatically without disturbance, even a tiny scale, occurs during the succession. A common idea on forest dynamics is that a forest community is a continuum of

gap/path cycle, and the climax is generally characterized by combinations of mosaics that line in different stages. The undulation of popnlations in a climax forest is largely depending on the changing of certain environment factors that are often caused by the turnover in high strata. Such changes may be brought about by a sudden destruction, or by the quantitative alternation of size conditions during natural succession, and, thus, the cycling is repeated. An acceptable theory for the maintenance of climax is that disturbance is a key factor driving succession. Climax species are usually shade tolerant, and they need tiny gaps for regeneration (Spies *et al.* 1995). *Pinus* is s typical species which needs light release for recruitment. It can survive under canopy but will wither before entering into canopy layer unless light is released from canopy layer (Wu *et al.*1992). In the study region near the plot, secondary forest dominated by deciduous species is very common, and in which, immense sapling of *Pinus* can be found on the ground, and this relates the characteristics of the species that proper light condition is favorable for its regeneration. *Fraxinus* is also abundant in secondary forest. As to the regeneration of *Quercus,* it is strictly limited if there is no enough direct radiation. *Tilia amurensis* and *Acer mono* had the best capability of self maintenance. The mechanism for the sustaining of the climax status, as well as the constancy of the climax species can be considered the result of disturbance, mainly windfall, and this needs precise study.

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